pyrheliometer, we can not be sure that the heat is fully recorded. I have found (Atmospheric Radiation, pp. 13–16) that such thin strips lose their heat mainly by convection, and that two minutes may elapse before complete convective and conductive equilibrium is established. In some of these instruments, the rear surface is left bright with the intention of confining the loss of heat chiefly to the front surface; and this would be thereby accomplished satisfactorily did not convection form so essential a part of the total loss. This, of course, goes on as well at the bright surface as at the dark. The heat produced by absorption of solar radiation at the blackened surface, escapes more easily than it enters, because the thin layer of black absorbent material transmits the long outgoing ether-waves much more freely than it does the shorter waves coming from the sun. Thus, it appears probable that the indications given by all of these so-called "absolute" actinometers are a little too small, and that we should not depend too much upon the agreement of measurements by different instruments and methods, since these may have equal constant errors. The only remedy for these defects lies in a most searching investigation of the complete theory of these instruments.

ICE CAVES AND FROZEN WELLS AS METEOROLOGICAL PHENOMENA.

By H. H. KIMBALL, Weather Bureau.

INTRODUCTION.

On page 71 of the MONTHLY WEATHER REVIEW for February, 1901, the Editor has stated that numerous natural ice caves are on record analogous to the interesting example near Flagstaff, Ariz. At his suggestion a special study of the literature bearing on the subject was undertaken by me, and I am now quite ready to agree with Mr. J. Ritchie, Jr.,[1] who says that "The best informed of scientists, even, are not aware of the mass of matter that has been written and published on this subject, owing to its distribution through the proceedings of so many learned societies." It was not until much time had been spent in searching through these proceedings, as well as through other departments of literature, that I became aware of a book entitled Glacières or Freezing Caverns, published in 1900, by Edwin Swift Balch, a member of the Philadelphia bar, and ex-president of the Geographical Club of that city, in which he mentions over one hundred and fifty authors whose writings were consulted by him in the preparation of his book. He also gives a list of some sixty-five places where subterranean ice forms in the United States, and nearly three hundred places for the whole world.

European ice caves.—So thoroughly has Mr. Balch covered this ground that it seems hardly necessary for me to review it. Mention will be made, however, of a work entitled Ice Caves of France and Switzerland, by Rev. G. F. Browne (London, 1865),and also of an article in Once a Week, Vol. II, p. 639, by Mr. Harold King, in which he gives an account of a visit to the famous Schafloch, an ice cave in Switzerland. From the descriptions of these two writers, in conjunction with those of Mr. Balch, it is evident that many of the ice caves of Europe are very grand affairs. Not only are the bottoms and sides ice coated, the latter often to unknown depths, but stalactites and stalagmites of great size and beauty are frequently to be found, giving the caves most fantastic appearances.

But the ice caves of the United States, if not so grand as those of Europe, are equally as interesting from a meteorological point of view. We therefore quote from several writers, in order that it may be seen under what a variety of conditions subterranean ice deposits are to be found.

[1] Paradoxical Phenomena in Ice Caves, Science Observer, April, 1879.

Ice cave in Washington.—In the Overland Monthly for 1869 Vol. III, p. 425, Mr. R. W. Raymond has given an account of a visit to a cave in Washington, in the Cascade Mountains, from which at that time ice was "packed" on the backs of mules and horses. He describes the cave as a channel in the basalt through which the melted lava continued to flow after the surface had become cooled and formed a crust. When, from any cause, the source of the melted lava has been cut off, these channels have been left empty, and it is in them that the ice is found.

Decorah, Iowa, ice cave.—In the Scientific American for March 29, 1879 (Vol. XL., p. 196), there is a description of a cave near Decorah, Iowa, by an anonymous writer, who thought that the ice formed in it only in summer and melted away every winter. But in the Scientific American Supplement for November 26, 1898, Mr. Alois F. Kovarik published the results of systematic observations of the temperature and the formation of ice in this cave, showing conclusively that the temperature fell steadily during the winter, that ice formed during the spring, and disappeared during the latter part of the summer.

These two caves, with the one near Flagstaff, Ariz., already mentioned, appear to be among the best examples of natural ice caves that are to be found in the United States, although there is a deposit of ice in the abandoned Cheever Mine at Port Henry, N. Y., that is fully as extensive. In all these cases the ice is deposited at a point in the cave considerably below the level of the entrance.

Ice beds in Connecticut.—In years past there have appeared descriptions of ice deposits that were to be found in deep ravines and gorges in the towns of Meriden[2], Northford,[2] and Salisbury,[3] Conn. In caverns or among the loosely piled boulders at the foot of the nearly precipitous sides of the ravines and under the shade of forest trees ice was said to form in winter in large quantities, and the rocks and trees protected it from the heat of summer so effectually that it was sometimes preserved until the early autumn. Of late years the existence of these ice deposits appears to have been nearly forgotten. In fact, recent letters to voluntary observers and others in or near these towns have generally elicited the statement that the ice formed only in a small way and was not preserved much longer than at other points in the forests among the mountains of that region. But our very energetic observer, Mr. L. M. Tarr, of New Haven, Conn., personally visited the ravine at Northford on June 19, 1901, with a party of friends, and reports as follows:

"Not far from the ravine the side of the mountain, which is composed of broken trap rock, is very steep. There are many trees on the top of the mountain and a few at its base, but during the most of the day this mass of rock is exposed to the direct rays of the sun. In these rocks, about 4 feet below the surface, much to my surprise we found ice. It was bedded in between the rocks, and could be taken out only in small pieces. There was considerable dirt mixed with it, as stated by Professor Silliman in 1822. I had my camera with me and took a snap shot of the place. (See Plate I, fig. 1.)

"The trees in the background of the print are on the edge of the ravine, which we examined throughout its entire length. At its bottom, near the base of the mountain, it is filled with small boulders, and under these are heaps of dead leaves and rubbish. I dug under some of the heaps of leaves, but found no ice. In ascending the ravine, we found two or three places where very cold water was trickling out of the rocks. I thought its temperature was not far from the freezing point, and concluded that it came, not from a spring, but from melting ice among the rocks. These were too heavy to move without a

[2] Silliman's American Journal of Science and Arts, 1822, vol. 4, pp. 174–177.

[3] Silliman's American Journal of Science and Arts, 1824, vol. 8, p. 254.

crowbar, which I did not have, and so could not investigate further.

"The ravine is very narrow, and, while well covered with trees, the shade is not so dense but that some sunshine penetrates it. I made an exposure with my camera, and inclose one of the prints. (See Plate I, fig. 2.) The picture was taken about half way up the ravine, but is a fair sample of its entire length.

"Although we did not find ice in the ravine, I have no doubt about its being there, and with a crowbar to move the rocks I think I should certainly have found it. I was surprised to find ice at Northford in such an exposed place, as the winter was not very cold in this vicinity, the snowfall very light, and the rains during April and May were unusually heavy."

Mr. Tarr writes that while the ravine at Meriden is much better known than the one at Northford, he has not been able to visit it personally; but from the accounts given him by others, it appears that little change has occurred there since Professor Silliman visited the place in 1822. This, says Mr. Tarr, is the testimony of Prof. A. W. Wright, of Yale, who visited the ravine in 1860; of Mr. Henry Hopkins, of New Haven, who found ice there on July 4, 1883; and of Prof. H. E. Gregory, of Yale, who found ice there during the summer of 1899, after the severe winter of 1898–99, but none during the summer of 1900, after the mild winter of 1899–1900.

Ice Mountain, Northriver Mills, W. Va.—Of a somewhat similar character is the celebrated Ice Mountain at Northriver Mills, Hampshire County, W. Va. Many descriptions[4] of this mountain have been given, and in all of them the ice is said to form in winter among the loosely piled boulders which compose the talus at its base. This ice slowly melts away during the summer, but at some little depth below the surface of the rocky heap it may be found throughout the year. Kercheval mentions a small log hut that had been built among the boulders by the owner of the property for the preservation of his milk, butter, and fresh meat, and states that when he visited the place, late in April, the openings between the logs in the side of this dairy next to the mountain, for eighteen inches or two feet from the floor, were completely filled with ice which also covered about one-half the floor to a depth of several inches. Mr. Duners, the owner of the property, informed him that milk, butter, or fresh meat of every kind were perfectly safe from injury for almost any length of time in the hottest weather.

Mr. George Deaver of Northriver Mills, W. Va., and Mr. R. H. Cookus, Voluntary Observer, United States Weather Bureau, Romney, W. Va., in letters of recent date, both testify that the ice still forms as in years past, and that the amount depends somewhat upon the snowfall of the previous winter, but that it can always be found at any season of the year by digging deep enough among the rocks. The old dairy building has, however, disappeared.

In the American Journal of Science and Arts, for 1844, vol. 46, page 331, S. Pearl Lathrop, M. D., has given a similar account of an ice mountain, or ice bed as it is called locally, in Wallingford, Rutland County, Vt.

Snow hole, Pownal, Vt.—In the American Journal of Science and Arts, 1818, Vol. I, p. 340, Prof. Chester Dewey of Williams College has given an account of a snow hole, apparently near the foot of West Mountain in the town of Pownal, Vt., about a mile from the southwest corner of the State. He says:

"The rocks are cleft in several places, and in one to such a depth that the snow and ice remain there through the year. The snow hole is about 30 feet long and nearly as deep at the east end, ascends to the west or toward the summit of the ridge, and is from 10 to 20 feet wide. When I visited it in June the snow was 6 feet deep on ice of unknown depth."

In Volume IV, p. 331, of the same journal, is an account of a visit to this snow hole in July, 1800, by Mr. H. A. S. Dearborn, and also of another visit by Mr. Thomas Ives of Yale College in July, 1818. Both found plenty of ice and snow. Mr. Ives adds:

"There is likewise a thick growth of evergreens and other wood about the entrance, which contribute to exclude the sun's rays. It is designated in the neighborhood by the name of the snow hole, the contents being rather snow than ice, a mixture of both."

In the same journal, Vol. V, p. 398, Professor Dewey mentions a visit to this place in August, 1822, when he found that the trees had been cut down to such an extent that very little snow or ice was to be found in the snow hole. He ventured the prediction that "The hand of man will probably destroy these natural depositories of snow, and in a few years they will doubtless be known only as the places in which snow used to be preserved through the year."

In Hitchcock's Geology of Vermont, Vol. I, p. 192, is a description of a frozen well, about a mile southwest of the village of Brandon, Vt. Similar wells have been noted at several places; among others, one at Owego, N. Y., which is described in Silliman's Journal of Science and Arts for 1839, vol. 36, page 184. In this latter the water froze so hard each winter, and remained frozen so late in the summer, that in 1855 it had been abandoned and the walls allowed to fall in.

ORIGINAL INVESTIGATIONS.

As reports indicated that the well at Brandon was still in good condition, and since the formation of ice in it, as well as in caves, seemed to be a meteorological phenomenon deserving of investigation the writer was recently instructed by the Chief of the Bureau to visit this well, and also the iron mines at Port Henry, N. Y., certain caves in the vicinity of Brandon, Vt., the so-called ice mountain at Wallingford, Vt., and a pit known as the "Refrigerator" at Cavendish, Vt., for the purpose of making a special study of subterranean ice deposits.

Mines at Port Henry, N. Y.—Leaving Washington on the evening of August 11, 1901, the first point visited was Port Henry, a charming town on the crest of one of the lower tiers of hills that rise in successive ranges, one above another, from the western shore of Lake Champlain. It is at the summit of one of the higher ranges, about 1,400 feet above the surface of the lake, that the Port Henry Iron Ore Company and the Witherbee, Sherman Iron Ore Company have sunk their shafts. There is nothing unusual about most of the mines. They are described as being warm throughout the year—too warm for health, in fact. But Mine No. 21, of the Port Henry Iron Ore Company is remarkable in that ice is found in it throughout the year, and in winter it is so cold as to cause suffering on the part of the miners. Few observations of temperature have ever been taken in this mine, but the superintendent, Mr. Pierce Clonan, informed me that one bitter cold day in January, 1897, when the miners were complaining more than usual, he hung a thermometer in one of the levels, and after an hour or so it read —38° F. The miners were never informed of this observation, for fear they would refuse to work.

The reason for this remarkable cold is not difficult to give. Some years ago mining experts decided to blow off the roof of this mine, and the heaviest charge of dynamite that had ever been fired in this country was used. As a result the entrance to the mine is now a deep pit several hundred feet in diameter at the top, but tapering to a shaft only a few feet in diameter at the bottom, 500 feet below. Previous to this explosion, when No. 21 was a closed mine, it was warm like the others. Since then it has been a cold mine. When the

[4] See Kercheval's History of Virginia, Winchester, 1833. Historical Collections of Virginia, H. Howe, Charleston, S. C., 1846. Maxwell and Swisher's History of Hampton County, Va., etc.

September frosts appear at the surface the cold frosty air of early morning settles through the wide mouthed pit into the levels below, and frost and icicles commence to form there. As the cold of winter comes on the cold in the mine keeps pace with it, but with this interesting modification; a bright sunny day in midwinter, with a crisp northwest wind, is often a bitter cold day in the mine. This is perhaps due to the fact that during our coldest winter mornings, which are often followed by bright sunny days, the cold, dense air gravitates to these low levels, while the warmer air of midday has no tendency in that direction.

Mr. Clonan informed me that in general a northwest wind was accompanied by cold weather in the mine and a south wind by warm weather. But this is also true at the surface. However, since the general direction of the levels is south from the shaft, a northerly wind would blow directly into them and a southerly wind away from them, and this might have some effect upon the temperature in the mine.

It was on the morning of August 13, 1901, that in company with the Assistant Superintendent, Mr. Edward Clonan, a visit was made by me to this mine. We descended in one of the ore buckets that run on a track that is inclined at an angle of about 60° from the horizontal, and that rests on the north side of the pit already described. It was a beautiful, bright morning, and just before starting the temperature in the shade of a building was 66.0°, and the relative humidity 71 per cent. Almost immediately after we commenced to descend the fall in temperature was noticeable. The deep pit was full of cool air. Considerable water was trickling down the south side of the pit, and near the bottom it was running over a sheet of ice. Just below the ice sheet was the opening to an old level, with icicles hanging from the roof, while on the floor of the level was an ice stalagmite, locally known as the "iceberg," that was not less than 6 feet high and 30 feet in diameter at its base. One side of it had been melted away by the water dropping from above. The temperature of the air just above this ice, 470 feet below the surface, was 36.4° F. In a little pool on the surface of the ice the temperature of the water was 32.0°.

Numerous observations were taken in the various levels with a Weather Bureau sling psychrometer, and the following table is a summary of the results:

Observations at Port Henry Iron Ore Company, Mine No. 21, August 13, 1901.

Time.	Place of observation.	Psychrometer.		Relative humidity.
		Dry.	Wet.	
		°	°	*Per cent.*
8:15 a. m.	Outside, near mouth of pit	66 0	60.0	71
8:35 a. m.	500 feet b low the surface.	37.2	37 0	98
.....	536 feet below the surfa e	37 2	37.0	98
.....	536 feet be ow the surface	36.8	.....	.....
.....	536 feet b lo the surface	36.2	.....	.....
.....	556 feet below the surface	37.1	.....	.....
.....	550 feet below the surface	38.6	.....	.....
.....	550 feet below the surface	39.0	.....	.....
.....	470 feet below the surface	36.4	.....	.....
9:50 a m.	500 feet below t e surface	37.8	.....	.....
10:20 a. m.	Outside, near mouth of pit	71.0	62 5	62

The lowest air temperature, 36.2°, was taken at what is known as the center of the mine, nearly under the iceberg; the next lowest temperature, 36.4°, on the surface of the iceberg; and the highest temperature, 39.0°, at the lowest level, in a "heading" where ore was being taken out. In general the temperature was higher in the newly extended portions of the levels than in the older portions. The superintendent attributed this to the fact that there was not so much moisture here and consequently less evaporation, but I am inclined to attribute it to the fact that the newly uncovered rock surface is not so cold as surfaces that have been long exposed to the air. In the severest winter weather the fresh dug ore is not frozen.

This mine is considered a very dry mine but in summer there is water running in most of the levels, coming in principally from the surface. It commences to freeze in September and remains frozen until the following May. A winter thaw is dreaded because it sends large quantities of water into the mine over the ice, and unless it is promptly drained into the "basin" and pumped out of the mine the accumulation of ice becomes serious. In fact, the only considerable accumulation of ice is at the iceberg on the old 470-foot level, the face of which is filled quite full each winter. If left to itself no doubt great quantities of ice would accumulate in the lower levels of the mine, as has been the case in the abandoned Cheever Mine, at Port Henry, which I am credibly informed has nearly filled with ice, and a few years since, when the supply in the local ice houses failed, ice was taken from this mine and sold to the citizens of the town.

I took an air meter into Mine No. 21, and near the bottom of the pit by which we entered a slight movement of the air out of the mine was apparent. Farther in, and on the lower levels, not a particle of movement could be detected, and the fog from our breath rose slowly and very nearly vertically. The currents are said to be strong in winter, particularly with a northwest wind. The air was filled with a bluish smoke, closely resembling fog. It is said that in damp weather the fog in the mine is dense.

Miller Pit is an abandoned mine close by No. 21; and standing on the surface, beside the rather open entrance, ice could be seen not more than 100 feet below, where the water flowing in from the surface was frozen during the past winter. It was here that a boy lost his life on July 4 last; while attempting to obtain some of the ice he slipped upon it and fell down the shaft to the bottom of the mine.

The Pittsford, Vt., ice cave.—The next day, August 14, in company with Mr. C. E. Farrington of Brandon, Vt., a visit was made to the Pittsford ice cave, about 9 miles southeast of Brandon. Although the existence of this cave has been known to the people in its vicinity for at least a century, very little has ever been written about it. It was brought to my attention by a press report of a descent into it by Professor Adrian Ronalds of Rio de Janeiro, and his daughter. The report stated that the descent was very dangerous; that the temperature of the cave was far below freezing; that an icy blast of great strength was blowing out of it; and that Professor Ronalds dug out of the ice a frog that had been imprisoned there not less than 2,000 years. Evidently this report needed to be accepted with due allowance for exaggeration.

The cave is located on the side of a mountain spur known as Ball Peak. Leaving our carriage at the foot of this peak, a climb of about one-third of a mile brought us to the entrance of the Pittsford Ice Gorge, which lies between Ball Peak and East Peak. This gorge resembles somewhat the ravine at Northford, Conn., shown on Plate I, fig. 2, except that its sides are steeper, the boulders covering its bottom larger, and the trees smaller. Just before entering it, at 12:25 p. m., an observation with the psychrometer under the shade of a tree gave a temperature of 76°, but no sooner were we inside than we were aware of a marked fall in temperature. Between the boulders in the bottom of the gorge were many small pits or caverns, and in some of these it was possible to measure the temperature at a depth of 5 or 6 feet below the surface. In one, not more than three rods from the entrance to the gorge, the temperature was 50°; in a second, a little farther in, it was 46.8°, and in a third, still farther in, 45.8°. Moisture was deposited upon the boulders forming the sides of the caverns, and also on the few ferns they contained.

Our guide informed us that in winter snow fills the gorge to a great depth. When it melts away in the spring ice must

form in the spaces among the boulders to a considerable depth below the surface, and some of it may be preserved throughout the summer. But there was none in sight and we could not penetrate the loosely piled rocky mass except in the small caverns here and there, as above stated.

The gorge rises as we advance, and near the summit, where the rise is unusually steep, there is a small hole in the side of Ball Peak that might easily be passed unnoticed. We enter and find ourselves in a small vestibule, in the floor of which is an opening some 6 feet in diameter. Against one side of this rests a substantial ladder. We light our lanterns and descend to the first landing, not over 20 feet below. A steeply inclined pathway into the mountain takes us about 30 feet below the entrance, and to the edge of a dark and apparently bottomless pit. But there is a small opening on one side of the passageway, and into this we slide, feet foremost. A winding tunnel presently brings us into the pit we had seen from above.

Almost immediately we step upon a mass of broken ice that covers the rocky decline leading to the center of the pit. This ice undoubtedly marks the bed of the stream by which surface water enters the cave from the gorge in the springtime. There is a similar frozen stream at the other end of the pit. At the bottom is a sheet of ice about 12 feet wide and 20 feet long. We can only guess at its depth, but the fact that here and there the point of a rock protrudes through it indicates that it is not deep. This inference is confirmed by the statement of our guide that he has seen the bottom of the pit perfectly dry later in the season. He also states that early in the spring the ice is sometimes 20 feet thicker than at the time of our visit, but the little frozen rivulets above mentioned indicate that in the spring of 1901 it was not more than 4 or 5 feet thicker than now, in August.

The appearance of this pit in the feeble light of our two lanterns was imposing. The sides are of solid rock, without seams. Separated from each other at their bases by a space of about 12 feet, one side stands nearly vertical, while the other leans over and rests against it about 30 feet above our heads. There is a passageway leading from the pit farther into the mountain which we did not explore.

Observations with the psychrometer while standing on the ice gave an air temperature of 35.2° and a relative humidity of 98 per cent. The air was very clear, in marked contrast to the air in the Port Henry Mine. While the sides of the pit were covered with moisture, probably from condensation, no water was flowing into it, and there was none on the surface of the ice. In a narrow space between the ice and the side of the pit the water had a temperature of 32.2°.

As we clambered out of the cave we saw daylight through a passageway leading from the landing at the foot af the ladder. It is possible to enter the cave through this passageway, therefore, in fact, the bottom of the pit is only about 40 feet below an opening communicating with the outer air. The temperature at this landing was 57.5°.

It seems perfectly clear that the air in this cave, as well as its rocky sides, are cooled to a very low temperature in winter. During the "spring thaw" water flows in from the surface, and is frozen. During the summer the temperature rises very slowly, since heat both from the interior of the earth and from the surface is conveyed but slowly by the rocks, and there is no tendency for the warm surface air to flow in and replace the cold, dense air of the cave. Our air meter failed to detect the slightest movement of the air either in the passageway leading to the pit, or in the pit itself.

Leaving the cave we climbed up the side of the gorge, and passing directly over the top of Ball Peak (elevation about 1,700 feet) we returned to our carriage at the foot of the mountain. The temperature on the summit at 1:45 p. m., was 78.4°, and at 1:55 p. m., a short distance below the entrance to the gorge it was 79.0°.

Bat Cave, Chittenden, Vt.—A drive of six miles northward along the side of the mountain brought us to the foot of Mount Chaffee, in Chittenden. We climbed up the side of this mountain about a half mile, to Bat Cave, which was reported to have very low temperatures in some of its compartments. The entrance to this cave is under an imposing stone arch that is tilted at a considerable angle with the horizontal. We descended a short distance by an inclined pathway, and then found ourselves on the edge of a precipice, with a dark pit of unknown depth below, as was the case in the Pittsford ice cave. And here also we found an opening into a tortuous tunnel, through which we slid, feet foremost, into a commodious apartment about 20 feet below the entrance. At 4:55 p. m., just before entering, the air temperature outside was 72.0°; here it was 47.4°.

There is a small hole leading out of the farther side of the compartment, so small that our lantern had to be extinguished, pushed ahead endwise, and relighted. Then, while lying flat on our stomachs with our hands straight out in front, by digging our toes into the soft dirt that constitutes the bottom of the cave, we were able to push ourselves ahead inch by inch. We confess to a creepy sensation when we were well into the hole, which we fitted like a finger in a glove, so that our hands and arms were quite useless.

This passage passed we found ourselves in a compartment of sufficient size to permit of swinging our psychrometer without difficulty. Here the temperature was 47.2°.

A passageway no larger than the one by which we had entered, and anything but straight, led out of the farther side of this second compartment. We did not consider it prudent to extinguish our light and try to advance in the dark by such a path, so we abandoned further exploration and crawled out of the cave as we had crawled in.

I do not think ice could be preserved in this cave for any length of time. The open mouth of the first compartment readily admits of the circulation of air through it. The other compartments are on the same level with the first, and hence must have about the same temperature. Consequently, while this cave should become very cool each winter it is readily warmed each summer.

Silver Mine, Brandon, Vt.—There is an abandoned silver mine near Bat Cave that, the owner informed me, often contains ice throughout the year. Some years since, when about to resume operations, a great quantity of ice had to be removed by forcing steam upon it through a pipe.

There is an interesting legend connected with this mine. As told by the present owner, the mine was worked by the Spaniards before the country was settled by the English. When they abandoned it they left behind large quantities of silver, some in bars and some in Spanish dollars. The presence of all this treasure was made known by one of the Spaniards, the last survivor of the band of miners, who returned when an old man and searched in vain for it until his death. The search has been continued at intervals by different parties until now, the present owner having spent the best part of his life in this work. He is thoroughly convinced of the existence of the treasure. A legend similar to this, except that the treasure is located at Wallingford, Vt., is related on page 841, Vol. II, Hitchcock's Geology of Vermont.

Ice bed, White Rock Mountain, Wallingford, Vt.—Reference has already been made to the ice bed at the foot of White Rock Mountain in Wallingford. On the afternoon of August 15, in company with Messrs. C. S. Saunders and C. N. Batcheller, a visit was made to this mountain, the general appearance of which is well shown in Plate II, fig. 1. Near the foot of the mountain, on the southwest side, is an immense talus of quartz rock, the characteristics of which will be understood

from Plate II, fig. 2., which is from a photograph by Mr. Batcheller. I crept in among the boulders near the foot of the mountain a distance of 10 or 12 feet, and found the temperature to be only 45.1°. At another point, a little higher up, the temperature was 46.7°, and at a third point, very near the first, it was 45.0°. The surface air temperature halfway up the talus was 70.0°, and a spring of water flowing out from under the base had a temperature of 41.1°. By the side of the spring air temperatures of 56.2°, 65.0°, 57.7°, and 64.0° were obtained within the space of a few minutes, showing the influence of cold air currents that were flowing out from among the boulders. While no ice was to be seen, Mr. Saunders assured me that it could usually be found there throughout the year, and that it had been found not more than two weeks previous to my visit. The very low temperature of the spring water, as well as of the air flowing out from among the boulders, indicates the presence of ice in considerable quantities at inaccessible depths in the talus.

Wherever we went among the mountains we found the most beautiful springs of pure, clear, and sparkling water; but this one at the foot of White Rock Mountain was by far the coldest. The most copious was at the foot of Mount Chaffee, in Chittenden, and it had a temperature of 45.8°. A smaller one, a short distance below the entrance to the Pittsford Ice Gorge, had a temperature of 52.0°.

The Refrigerator, Cavendish, Vt.—Near the foot of the gorge on the Black River at Cavendish, Vt., is a sort of open pit, which is sheltered from the direct rays of the sun by forest trees. In this pit the snow and ice naturally accumulate in winter, and do not disappear until late in the spring. For this reason it has received the name "Refrigerator," which it scarcely deserves, since its temperature on the day of our visit, August 16, was 66.4°, while a short distance above it, on the bank of the gorge, the temperature was 75.2°.

Frozen Well, Brandon, Vt.—In the mines at Port Henry, in the Pittsford ice cave, and in the talus at the foot of White Rock Mountain conditions are such that considerable quantities of ice can be stored up each winter where it will be protected from direct radiation, and also from air currents in summer. In fact, these places have very appropriately been called natural ice houses. In the frozen well at Brandon we now have to consider a phenomenon that has been thought by some writers to be of a somewhat different character.

A great deal has been written about this frozen well. Hitchcock, in his Geology of Vermont, devotes several pages to it, and Balch refers to it several times in his Glacières and Freezing Caverns. Formerly it was considered one of the curiosities of the town, and it was customary to conduct visitors to it. Of late years it has become an old story with the residents, and comparatively few people visit it. Indeed, it is quite commonly reported that the well has lost its virtue and no longer freezes as formerly. This is not the case. The well still freezes each winter, and this year remained frozen solid until after June 1. On August 13, the date of my visit, the temperature of the water was 42°. A lantern was lowered to the bottom and no ice was to be seen. Light streamers of paper were attached to the sides of the lantern, and they failed to detect any movement of air through the well.

We talked with the owner, Mr. C. V. Luce, who stated that when the well was dug in November, 1858, a layer of frozen gravel was struck at a depth of fourteen feet, underlying a layer of clay. The frozen stratum had a depth of from twelve to fifteen feet, and below it was a second layer of clay, under which water was found in a gravel formation. For some years after the well was dug the ice accumulated in it in such quantities that it had to be abandoned during the winter months, and it always froze solid. It was then the custom to cut a hole through the ice to the gravel below on Memorial Day (May 30). No water would appear at first, but after a few hours the hole would be filled with it, and ice would form on its surface. A blow from the bucket was sufficient to break through this ice, however. Later a tight cover was made for the well, and the ice that formed at night, even in mid-winter, could be broken in the morning by dropping upon it a heavy sledge hammer attached to a rope.

It is worthy of note that while the water in this well has never failed, the supply is so small that the well can easily be dipped dry at any time.

Various theories have been advanced to account for the presence of the frozen stratum encountered when the well was dug. Hitchcock thought it of glacial origin,[5] and that it had been preserved through the intervening thousands of years, because it was so thoroughly insulated from heat, coming either from the surface or from the interior of the earth, that the cold due to evaporation from the earth around it was sufficient to maintain its temperature below the freezing point. Hager,[6] on the other hand, could not accept this explanation. He thought it more probable that the ice encountered had accumulated and been preserved in much the same manner as in the ice caves and in the mines at Port Henry.

The peculiar character of the geological formation in the vicinity of the well favors the penetration of the cold in winter to unusual depths. Plate III, fig. 1, shows the south end of a moraine that extends northeasterly for some distance from the valley of Otter Creek, passing close by the well. The valley of Otter Creek is seen in the background. Plate III, fig. 2, is a view of the interior of this moraine, taken in a pit near the well. At this point the moraine consists of pebbles, mostly of small size, perfectly free from sand or dirt. Water would flow freely through such a formation, and, under favorable circumstances, air should circulate through it. Plate III, fig. 3, shows the formation on the southeast side of the moraine somewhat nearer the well, where the pebbles are slightly coarser, and are cemented into a conglomeritic mass, which may be broken in pieces by the hand.

Otter Creek Valley is supposed at one time to have been a lake, and this moraine was a shore of an arm of the lake. Deposit on the bottom of the lake formed what is now the soil of the meadows, and it naturally overlies the lower edge of the moraine. In digging the well the first fourteen feet was through deposit from the Lake. Then the pebbles of the moraine were reached, and it was in the interstices between these pebbles that the ice was found.

It seems rational to explain the formation of the ice in this stratum by the same general principles that apply to the other cases we have studied, if we can do so; that is to say, by a circulation of cold air during the winter between the pebbles composing the moraine, thereby lowering the temperature of the pebbles themselves, so that any water that may find its way in during the spring thaw will be frozen. We know that the natural tendency of the cold, dense surface air in winter must be downward to replace the warmer and lighter air beneath the surface. The passage of successive areas of high and low pressure will intensify this tendency, by alternately compressing and expanding the air beneath the surface. It is conceivable that each area of high barometer should force cold air beneath the surface, while each area of low barometer should allow warm air to flow out. It is also conceivable that the arrangement of the strata of the earth's crust might be such that the cold air would flow in at one point and the warm air out at another. A siphon movement might even be established, by means of which a cold current would continually enter the ground at one point and a warm current continually flow out at another.

There is evidence of just such a circulation through the

[5] Geology of Vermont, Vol. I, page 201.
[6] Hitchcock's Geology of Vermont, Vol. I, page 205.

strata composing this moraine. At a point on the side of the moraine not far from the well, and south of the gravel pit shown in Plate III, fig. 2, it was noticed in years past that the snow always melted in winter, so that the ground would be left bare, while all around it was covered with snow. This looks very much as though warm air was coming out of the ground at this point. The phenomenon has not been observed of late years, but this is not strange, since the configuration of the moraine has been much changed by excavations, and, as already stated, but little attention has been paid to the well. Such currents would naturally cease in summer.

We may therefore safely assert that the conditions here are unusually favorable for the circulation in winter of cold air through the stratum in which the ice was found. Furthermore, as has been pointed out by Hager and Hitchcock, the layers of clay both above and below the ice help to insulate it from heat in summer both from the surface and from the interior of the earth. We are therefore in accord with Hager[7] and Balch[8] in concluding that this well, like the ice caves, is a *natural refrigerator*.

Mines in McClellan Mountain, Colo.—An ice formation somewhat similar to that at the Brandon, Vt., frozen well is found at Georgetown, Colo., in the Clear Creek County Mines in McClellan Mountain. Mr. E. L. Berthoud[9] thus describes it:

"The discovery-drift of the Centennial Lode runs into McClellan Mountain at an altitude above 13,100 feet on a course southwest, at about 30 feet from the entrance of the tunnel. Intercalated in the vein I found three or four well defined veins of solid ice, parallel with the bedding of the rock, and filling all its thinner side cracks and fissures; in fact, after further examination, I found that the frozen stratum, and the congealed, hard earth, rock, and gravel began only a few feet below the accumulated rock and débris of the mountain slope, and continued as far as the excavation reached, some 40 feet in depth.

"From the Centennial Lode I went westward about 300 feet and examined the drift that has been excavated into the mountain some 500 feet upon the vein of the International Lode. Here there is repeated the same frozen substratum and the same rift or veins of ice in the country rock and in the vein. I went into the tunnel about 100 feet and found that this glacial condition still existed; the owner of the mine assured me that the ice and frozen rock continued all the way to the end of the tunnel and caused a good deal of extra expense in mining the ore.

* * * * * * *

"This is certainly a singular phenomenon when we consider that across the narrow valley north of McClellan Mountain, not over three-fourths of a mile distant, and upon another high peak, the limit of tree growth exceeds 12,400 feet elevation on the south slope of that peak.

* * * * * * *

"It has been suggested[10] that the frozen soil and rock of some mines examined by him, northwest from McClellan Mountain, on the west slope, have been thus left icebound since the Glacial Period, and that they thus retain their former icebound condition, from the excessive altitude of the mines there explored.

"This may be the case, but it seems doubtful.

* * * * * * *

"I am inclined to the belief that the glacial condition of McClellan Mountain is due to local causes. Prominent among these would be the loose nature of the soil and deep rocky débris of the mountain, and the slow percolation of water exposed to excessive evaporation that is promoted and quickened by continued gales from the north and northwest that strike against the precipitous face of the mountain range in that direction. The opposite slope, on the contrary, which shows the abnormally high timber line, faces a pass 13,100 feet high which gives a way perfectly unobstructed for south-southwest winds."

[7] Hitchcock's Geology of Vermont, Vol. I, p. 207.
[8] Glacières or Freezing Caverns, p. 79.
[9] Silliman's Am. Jour. Sci., 1876, vol. 111, p. 108.
[10] R. Weiser, Am. Jour. Sci., 1874, vol. 108, p. 477.

It is evident that ice caves and frozen wells are but different manifestations of the same phenomenon. In both cases the cold air of winter circulates to unusual depths below the surface, and freezes the small quantity of water with which it comes in contact. In summer this subterranean circulation of the air ceases, and heat finds its way to the ice only by the slow process of conduction. In consequence, the ice that accumulates during the winter and early spring may not entirely disappear during the following summer, but continue to accumulate for ages.

OUR KILLING HEAT.

By Gen. HENRY L. ABBOT, dated Cambridge, Mass., Aug. 21, 1901.
[Extract from Boston Transcript.]

In view of the general interest in tropical climates induced by recent events, perhaps you would like to receive figures extending the comparison to the Isthmus of Panama. I have just received the July sheets of two self-registering thermometers, which, for several years, have been in use by the New Panama Canal Company in its study of the elements which have a bearing upon the completion of its works now in progress on the isthmus. One station, Alhajuela, is situated about a dozen miles from the Atlantic coast, on the Upper Chagres River, where the reservoir dam will be placed; the other, La Boca, lies on the Bay of Panama, and forms the new terminal of the Panama Railroad. Both are nearly in latitude 9° north. The figures, therefore, present both the interior and the coastwise climates of the isthmus. The mean monthly temperature (including every hour of July) was at Alhajuela 77.4°, at La Boca 81.5° F. The table below exhibits the extraordinary uniformity of the climate, the mercury only once rising above 90°, and never falling below 80° at the hottest hour of the day. It may be added that this monthly record might represent any other month of the year, there being no sensible difference in winter and summer, although the range in the twenty-four hours is distinctly greater in the four dry months than in the eight rainy months.

Isthmian daily maximum temperature in July, 1901.

Date.	Alhajuela.	La Boca.	Date.	Alhajuela.	La Boca.
	°F.	°F.		°F.	°F.
1	82.	82.4	17	83.8	84.4
2	82.2	83 8	18	83.8	84 2
3	88.3	86.5	19	80.1	80.8
4	87.6	87.8	20	86.0	84.6
5	83.3	85.3	21	85.8	86.0
6	86.2	87.4	22	85.8	84.9
7	82.8	84.2	23	82.4	84.7
8	85.6	87.8	24	91.2	86.2
9	82.8	82.2	25	87.8	86.0
10	83.3	85.1	26	86.4	84.4
11	86 2	87.4	27	82.1	83.1
12	86.0	86.5	28	86.0	86.9
13	84.2	88.3	29	81.0	84.2
14	84.2	85.1	30	87.4	87.8
15	81.9	84.0	31	87.8	88.5
16	88.9	88.2			

These figures demonstrate, what is well understood, that it is the uniformity of the heat and not the highest temperature that is characteristic of the Tropics and that renders the climate oppressive.

FIG. 1.—Ice bed, Northford, Conn.

FIG. 2.—Ravine near ice bed, Northford, Conn.

FIG. 1.—White Rock Mountain, Wallingford, Vt.

FIG. 2.—Talus at base of White Rock Mountain.

FIG. 1.—Terminus, overlooking Otter Creek.

FIG. 2.—Gravel pit near frozen well.

FIG. 3.—Conglomeritic formation, between the pit and well.